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Risø-M-2442

HEALTH PHYSICS DEPARTMENT
Annual Progress Report
1 January - 31 December 1983

Abstract. The report describes the work of the Health Physics Department at Risø during 1983. The activities cover dosimetry, instrumentation, radioecology, risk by nuclear activities and nuclear emergency preparedness. Lists of staff and publications are included.

A great deal of the work in the department is of minor interest to people outside Risø as it represents service functions. Therefore, the main emphasis in the report has been placed on scientific and contractual work.

INIS Descriptors
DOSIMETRY; RADIATION PROTECTION; RADIOECOLOGY; RESEARCH PROGRAMS; RISOE NATIONAL LABORATORY.

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1. GENERAL HEALTH PHYSICS

The ordinarily health physical assistance and control at Risø National Laboratory is the duty of the Safety Department, but the Health Physics Department has the responsibility for some functions: Dosimetry, instrumentation, environmental monitoring, and health physical preparedness. More extensive education in health physics is also the responsibility of the department. Besides courses for the staff at Risø this includes shorter courses and lectures for nurses, fire brigade inspectors, naval officers and many others. Further, many of the staff members give lectures or otherwise assist in educational programmes at universities and give informative talks to societies and clubs.

For society at large, the department assists in answering questions and making statements or reports for the government and the central administration. Questions that relate to the Swedish nuclear power plant at Barsebäck, situated 20 km from the center of Copenhagen, have been of particular interest. The public concern about this plant has led to the establishment of a Danish-Swedish Committee with the purpose of investigating the hazard to the Danish community in case of an accident at the plant. In 1983-84 the department answered several questions for this committee and povided information at some of its meetings.

The Swedish Council for Nuclear Safety (RKS) asked the department to give two lectures at a seminar on "Radioactive Releases after a Nuclear Power Accident" in Stockholm, September 1983.

Finally, it should be mentioned that the department is represented in a number of international committees, the most important of which are listed in Appendix 2.

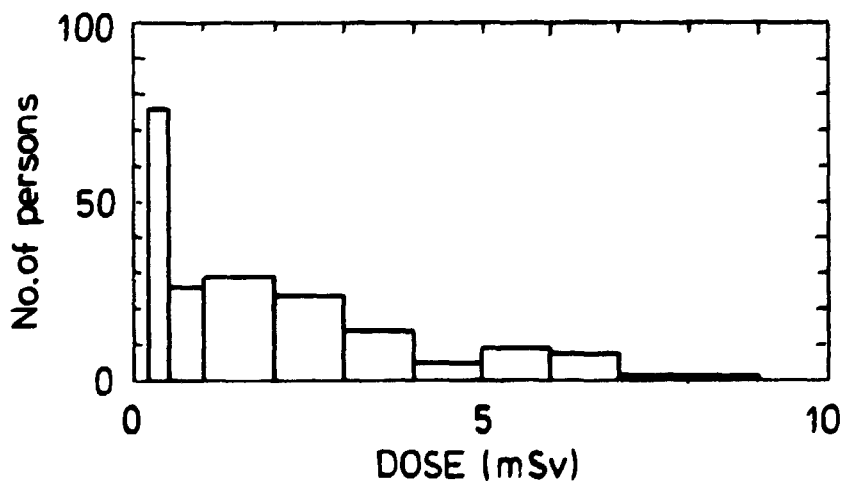
2.DOSIMETRY AND INSTRUMENTATION

2.1. Personal dosimetry

Risø's personal dosimetry service covers the individual monitoring of the personnel at Risø and the Niels Bohr Institute Tandem Accelerator. All workers and visitors staying at Risø for a period of more than two days are supplied with the Risø standard beta/gamma personal TLD badge. Additional dosemeters, e.g. fast neutron films, quartz fiber pen dosemeters, extremity dosemeters and criticality dosemeters are supplied according to special requirements. Urine samples are routinely collected in accordance with an established programme.

In 1983 2240 persons were monitored of these 193 persons received doses above the registration level for external doses of 0.2 mSv (20 mrem). The total dose (collective dose equivalent) registered to the monitored personnel was 0.33 man sievert (33 man rem). 12 persons received internal doses caused by intake of tritiated water. The contribution to the total dose from internal doses was 0.006 man sievert (0.6 man rem). Figure 1 shows the distribution of the levels of the registered doses for 1983.

Fig. 1. Distribution of yearly whole body doses (effective dose equivalent) from 1983 for the Risø personnel.



2.2. Accident dosimetry

In September 1982 a worker was accidentally exposed to gamma radiation at the Institute for Energy Technology in Kjeller, Norway. He died 13 days later as a consequence of the irradiation. Various methods were used to estimate the dose, including the measurement of thermoluminescence from jewels contained in the worker's wrist watch. These measurements were made in the Health Physics Department.

A total of 11 jewels were received from the worker's watch; it was found that only 3 of them were sensitive enough to give a reliable measure of the accidental dose. The dose to the worker's wrist was estimated to be 14.6 ± 2.9 Gy.

Subsequently, further studies were carried out in order to provide more information on the applicability of watch jewels as accident dosemeters. Three different types of jewels were investigated. The TL sensitivity was found to vary strongly from one jewel to another, and a significant fading was observed. For the most sensitive jewels the lowest detectable dose was of the order of 1 Gy.

2.3. Beta Dosimetry

A personnel dosemeter for routine application in mixed beta/ gamma fields requires a thin, preferably tissue-equivalent detector with an adequate sensitivity and with a mechanical strength and shape suited to handling in automatic as well as manual readers. Two techniques have been applied to produce TL dosemeters that are applicable for routine dosimetry and have a thin effective dosemeter thickness: 1) changing the transparency of TL detectors by adding graphite to the dosemeter material during the production process, and 2) creating a new glow peak in a thin surface layer of existing LiF TLDs using a boron diffusion process.

2.3.1. Graphite-mixed dosemeters

By incorporating graphite in TL-dosemeters the TL-emission can be limited to the surface layer whereby an energy response similar to that of a thin detector can be obtained. The presence of graphite in the dosemeter has no effect on the fundamental TL-characteristics of the TL-phosphor, and graphite-mixed dosemeters have the same mechanical strength as dosemeters without graphite.

The investigations have been concentrated on $Li_2B_4O_7$:Mn-dosemeters produced at Risø and MgB_4O_7:Dy-dosemeters produced at the Boris Kidric Institute of Nuclear Sciences, Yugoslavia. The dosimetric properties important for the application of these dosemeters for personnel dosimetry, e.g. photon dose response, dose threshold, reproducibility, beta-ray energy dependence and fading were investigated. Furthermore, the reliability of the dosemeters in field applications for one-month periods was studied by using a modified Risø personnel badge.

MgB_4O_7:Dy dosemeters with graphite content from 1 to 3% are appropriate for personnel dosimetry with respect to beta/gamma energy dependence, reproducibility and sensitivity. However, when applied to routine dosimetry over one-month periods the dosemeters occasionally showed unexpectedly high background doses. Investigations are in progress to explain and avoid these troubles.

2.3.2. Boron diffused TLDs

A new glow peak can be created in a thin surface layer of existing LiF TLDs by using a boron-diffusion process. The diffused surface layer functions as a thin detector. However, due to a significant influence from glow peaks close to the new high-temperature peak the applicability of these dosemeters to personnel dosimetry is limited.

2.4. Studies of CR-39 nuclear track detectors

CR-39 (allyl diglocyl polycarbonate) is a very sensitive track-recording polymer with possible applications in several fields, including neutron dosimetry and radon monitoring.

Studies of the nuclear-track-recording properties of CR-39 were initiated in 1982. In 1983 the work has mainly been concerned with radon measurements. CR-39 detectors were cut from sheets of a thickness of about 500 µm obtained from Pershore Mouldings Ltd. After irradiation the detectors were etched in a 6.25 N NaOH solution at 70°C for 16 h. When exposed in the passive radon dosemeter described below, the sensitivity of CR-39 was found to be about 5 tracks per cm^2 per $kBq \cdot m^{-3} \cdot h$ radon-222. Three times the standard deviation of the count from unirradiated detectors corresponds to a minimum detectable radon concentration of about 5 Bq/m^3 for a 3-month monitoring period.

2.5. Experimental investigation of measurement techniques for the determination of indoor radiation exposure

A dosemeter for measuring indoor radiation exposure has been designed. The dosemeter consists of a plastic cup which contains a TLD-package and two pieces of CR-39. The cup is provided with a perforated lid and a fibreglass filter that permits radon-222 to diffuse into the cup.

Twenty scintillation flasks have been made for spot measurements of radon concentration. For the measurement of radon daughter concentrations three sequential counters have been manufactured. Three counting periods and two intervals can be selected and preset, for example in accordance with the standard Thomas-Tsivoglou method. The counts are automatically printed out at the end of each counting period.

A number of the above-mentioned dosemeters have been exposed for calibration purposes in a radon exposure room and in a steel drum. The radon concentration in the steel drum is around 40 kBq m^{-3} and in tne radon exposure room around 2 kBq m^{-3}.

Simultaneous measurements of radon and radon daughters have been made frequently in the radon exposure room to determine the radon concentration and the equivalent equilibrium concentration (EEC) of radon. At the same time the standard Thomas-Tsivoglou method for measurement of radon daughters has been compared to the method suggested by Busigin. The results remains to be evaluated.

83 dwellings have been selected all over the country. 200 dosemeters were distributed as from 1 December 1983 for the first of two planned periods of three months. In each dwelling one dosemeter is placed in a living-room and one in a bedroom. Dwellings with a cellar have a third dosemeter installed there.

This research programme is supported by the Commission of the European Communities.

2.6. Environmental dosimetry

As part of the environmental monitoring programme carried out by Risø, gamma background exposure levels at different sites of Denmark are routinely measured by means of LiF TLD-700 dosemeters. The integration times used are 6 months for zones surrounding the Risø facilities and 12 months for selected sites elsewhere in the country. The mean exposure levels, normalized to exposure rates, for different parts of Denmark in 1983 are given in the following table:

Location	Mean exposure rate (μR/h)*
Risø zones	8.8
Zealand and islands	7.9
Jutland	7.2
Baltic island, Bornholm	10.6

*) cosmic component is included

Mean gamma background exposure rate levels for different parts of Denmark measured with LiF TL dosemeters in 1983.

2.7. Phantom for internal dosimetry

A phantom is under construction at Risø because there is a need both for an experimental validation of internal dosimetry calculations and development of a more complex mathematical phantom than the rather simplified one described by Fisher and Snyder.

Impressions have been made of real human organs and a copy of the organs have been moulded. These copies have been used to produce vacuum forms. Tissue-equivalent plastic sheets have been sucked into the vacuum form producing a shell with a shape identical to the original organ. Each organ have been made of two shells and assembled by glueing. The same procedure has been used to produce the body and the extremities. Thin tubes passing through the shallow organs make it possible to place TL-dosimeters in a matrix in the organ to measure the dose distribution in them. The organs will be placed correctly in the body using anatomical maps. The phantom has been supplied with lungs, liver, kidneys, spleen, stomach, GI-tract, bladder, pancreas, and thyroid gland.

Different radionuclides will successively be placed in a tissue-equivalent liquid solution in all the organs. Tissue-equivalent liquid will be filled into all the remaining organs and body, and the dose-equivalent rate distribution then measured by TL-dosimeters in all the organs including the source organ. For the lungs a special granulous material will be used instead of a liquid to account for the low average density of the lung tissue and air. The results will be compared to the values given in ICRP 30.

2.8. Instrumentation

Risø health physics instrument service covers routine calibration and maintenance of approximately 650 health physics survey instruments ot which approximately 50 are positioned outside Risø as part of emergency arrangements. In addition, the instrumentation group is responsible for the working and calibration of area- and effluent monitoring systems installed at nuclear facilities at Risø.

A 250-kV X-ray therapy unit, procured from a dismantled hospital, was modified and installed in the Health Physics department during 1983 for dosemeter and instrument calibration. A gamma irradiation unit containing a 230 Ci ^{137}Cs source was planned and designed as well to replace old decayed ^{60}Co gamma calibration sources.

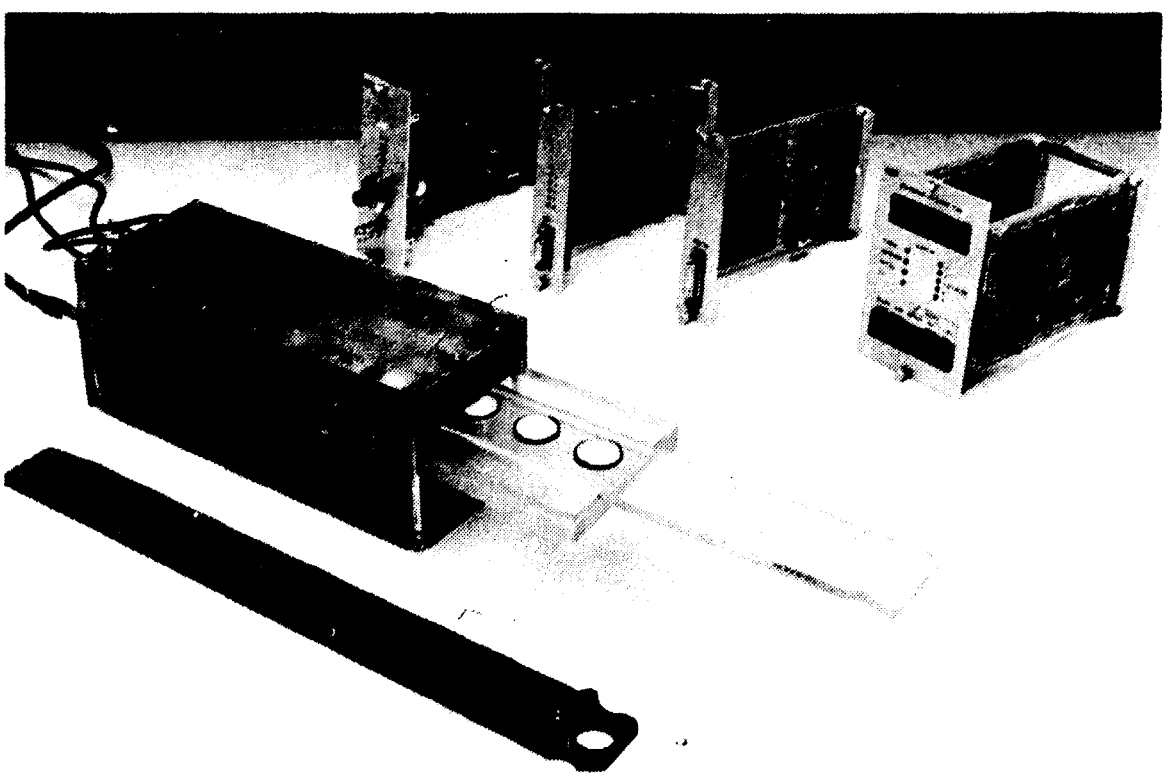
2.9. A new combined iodine/particulate effluent monitoring system at the hot cell plant

A new effluent monitoring system was designed and installed in connection with the ventilation system at the Risø Hot Cell plant. The new system - replacing old worn out monitors - is based on integrating effluent beta monitors. Radioactivity is accumulated concurrently with the release by suction of a fractional air flow from the ventilation channel through an air flow filter house incorporating a filter paper pack. Using beta- rather than gamma-detectors allow an operation of the monitors as a combined iodine/particulate monitoring system by incorporating a charcoal/glassfibre filter paper sandwich pack into the filter house. The effluent monitoring system partly consists of one 2-of-3 system placed in the common outlet stack that interferes with the control of the ventilation system whenever a preset alarm level has been reached. In addition, 4 single monitors are placed strategically in the ventilation system to maintain the survey of the origin place for the release.

A documentary report will be published in 1984. It includes a detailed technical description in addition to release criteria and iodine calibration.

2.10. Gas flow multicounters for low-level beta counting applications

The development of gas flow counters for low level beta counting applications was continued in 1983 and resulted in a new improved version of a 5-element GM multicounter system for the simultaneous counting of 5 samples of max. 25 mm diameter. The GM-25-5 low-level beta multicounter system partly consists of a mechanical gas flow counter unit (see photo) which incorporates 5 individual GM sample counter elements and a common guard counter. The guard counter reduces the background by using anticoincidence technique. Each sample counter element is provided with a mylar window with a density of approx. 1 mg/cm^2 and a diameter of 25 mm. The counters are gas flow types intended for a counter gas (99% Ar/1% isobutane or 99% Ar/1% propane) to flow continuously through the sample- and guard-elements. A sample slide allows 5 samples to be inserted into the multicounter and measured simultaneously. A lift mechanism minimizes the sample-to-window distance to obtain optimal efficiency.

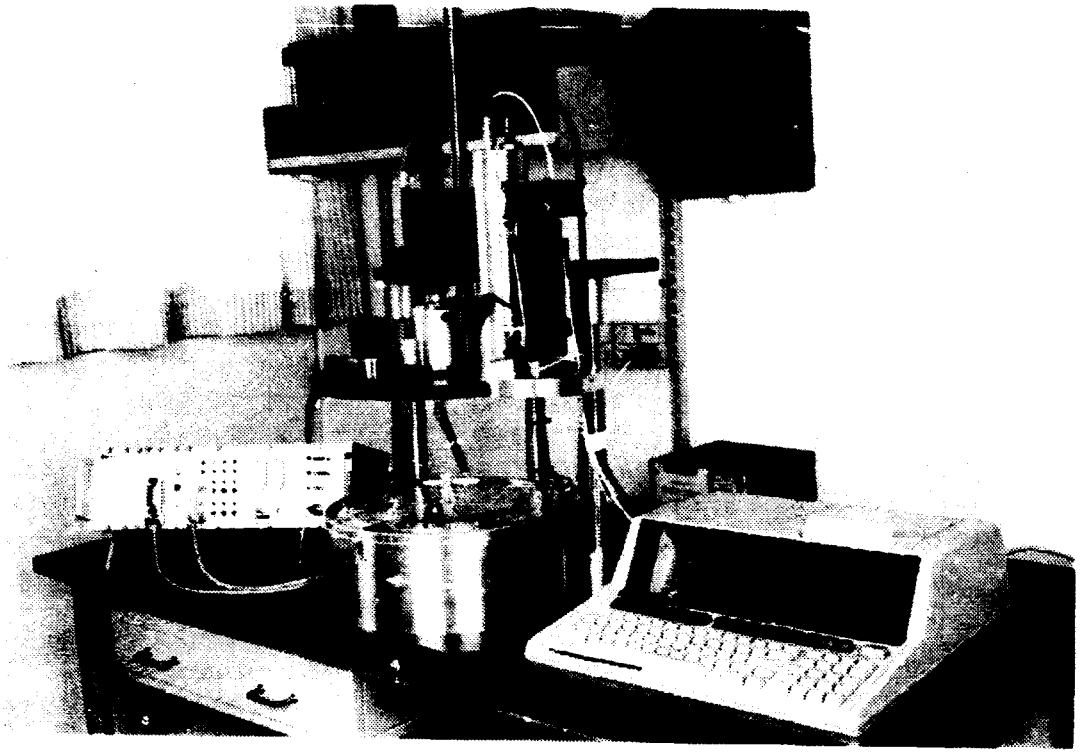


The background obtained with 100 mm lead shielding is approximately 0.2 cpm and the counting efficiency (2π) for samples of $^{90}Sr/Y$, ^{99}Tc and ^{14}C was measured to be 49%, 42%, and 24%, respectively. One multicounter system was delivered to the Department of Radioactivity of the University of Helsinki for the measurement of ^{99}Tc samples. Two systems (a total of 10 counting channels) were delivered to the Nordic Laboratory for TL Dating for the determination of potassium in feldspars. A feldspar sample with a potassium content of 1% has shown to yield a net beta count of 40 cph; the background is around 15 cph.

A completely new windowless gas flow multicounter with four elements was developed in cooperation with the University of Lund. The samples are placed inside the individual counter elements prior to sealing the counters with a lid and a gas flow is introduced. The windowless counter was initially developed to measure ultra low energetic beta emitters such as ^{63}Ni samples prepared electrolytically on steel plates.

2.11. TL instrumentation

Two fully automated TL reader systems for TL dating and a manually operated reader for research purpose were put into operation during 1982-83. All systems are controlled by HP-85 or HP-86 microcomputers; thus, flexibility in selection of measurement parameters, calculation of TL signals and display and printout of glow curves is achieved. The basic design of the automated reader system incorporates a 24-position microprocessor-controlled sample changer and a beta irradiator. The system automatically provides the data for constructing the primary and secondary response curves required for determining the archaeological and geological ages.



2.12. Calibration of gammacells for irradiation of biological specimens

A dosimetry method was used to calibrate a type of gammacell initially developed at Risø National Laboratory for the irradiation of blood. The gammacell which is now commercially available from the Mølsgaard Medical Company is a laboratory irradiator design operating with a stainless steel irradiation container (85 mm diameter x 180 mm).

The calibration comprises evaluation of calibration curves to be used for typical applications of the gammacell and estimates of the homogeneity of the doses given to the irradiated specimens. Sintered $Li_2B_4O_7$: Mn TL dosimeters were chosen for the measurements because of their good tissue equivalence, small size, and appropriate dose range. Individual dose response curves were used for each dosemeter to account for differences in supralinearity. A device consisting of four Perspex tubes placed at different distances from the centre in the irradiation container was used for the dose homogeneity studies. Each Perspex tube contained TL dosemeters at fifteen positions. The space between the Perspex tubes was filled with acrylamid gel.

List of publications

Bøtter-Jensen, L., Bundgaard, J., and Mejdahl, V. "An HP-85 Microcomputer-Controlled Automated Reader System for TL Dating". In: Third Specialist Seminar on TL Dating, Helsingør, 23-3] July 1982. Edited by T. Hackens. Part 2. Council of Europe, Strassbourg, 1983 (PACT Vol. 9 Part 2) 343-349.

Bøtter-Jensen, L. and Mejdahl, V. "Microcomputer-controlled reader systems for archaelogical and geological TL dating". Radiation Protection Dosimetry, Vol. 6, 193-196 (1983).

Christensen, P. "Calibration of gammacell for blood irradiation". Paper presented at the Nordic-Soviet Meeting on Standar and Applied Dosimetry, Helsinki, 9-11 November 1983.

Christensen, P. "Study of graphite-mixed and boron-diffused TLDs for skin dose assessment". Paper presented at Intern. Beta Dosimetry Symp., Washington, D.C., USA, February 15-17, 1983.

Lippert, J. "Detector-Efficiency Calculation Based on Point-Source Measurement". Int. J. Appl. Radist. Isot. 34, 1097-1103 (1983).

Majborn, B. "Studies of the dosimetric properties of watch jewels". Radiation Protection Dosimetry, Vol. 6, 129-132 (1983).

Prokić, M. and Christensen, P. "New type of TL dosimeter for personnel beta dosimetry". Paper presented at XI. Regional Congress of IRPA, Austrian - Hungarian - Yugoslavian Radiation Protection Meeting, Vienna, September 20-24, 1983.

Prokić, M. and Christensen, P. "Graphite mixed magnesium borate TL dosemeters for beta ray dosimetry", Radiation Protection Dosimetry, Vol. 6, 133-136, 1983.

3. RADIOECOLOGY

3.1. Environmental radioactivity

The studies of environmental radioactivity were continued in 1983. Strontium-90 was determined in samples from all over the country of precipitation, ground water, drinking water, seawater, dried milk, grain, bread, potatoes, vegetables, fruit, total diet, and human bone. Furthermore, ^{90}Sr was determined in local samples of air, rainwater, marine sediments, grass, sea plants, fish, and meat. Cesium-137 was determined in air, precipitation, sea water, sediments, milk, grain products, potatoes, vegetables, fruit, total diet, sea plants, fish, and meat. Estimates of the mean contents of radiostrontium and radiocesium in the human diet in Denmark were given. Tritium was determined in precipitation, fresh water and seawater. Plutonium and americium were measured in seawater, sediments, sea plants, and mussels.

The γ-background was measured regularly by TLD, ionization chamber and on site γ-spectroscopy at locations around Risø, at ten of the State experimental farms along the coasts of the Great Belt and around Gylling Næs.

The marine environment at Barsebäck and Ringhals were monitored for ^{137}Cs and corrosion products (^{58}Co, ^{60}Co, ^{65}Zn, ^{54}Mn).

Samples of various foods and drinking water from Greenland and the Faroes were analysed for ^{90}Sr and ^{137}Cs.

3.2. Studies in waters of the North Atlantic region.

In these studies the North Atlantic region comprises the waters around Greenland, the North Atlantic Ocean between the Faroe Islands and Greenland, and the North and Baltic Seas (including

the Danish Straits). In this region the salinity ranges from ocean water to brackish water, the climate from arctic to temperate.

Although fallout nuclides from nuclear weapons testing in the atmosphere are still the main source of manmade radioactivity, the discharges of radionuclides from the UK reprocessing plant Sellafield contribute measurably to the activity in the North Atlantic region. The radionuclides ^{137}Cs, ^{134}Cs, and ^{99}Tc originating from Sellafield are at present detectable in the North, Baltic, Norwegian, Barents, and Greenland Seas. The calculated collective effective dose equivalent commitment from Sellafield from all discharges of ^{137}Cs until now is $2x10^3$ manSv.

The studies are supported by the Commission of the European Communities.

3.2.1. Uptake and loss of certain nuclides by Mytilus and Fucus

In 1983 the laboratory experiments were conducted with the following nuclides: $^{239}Pu(VI)$, $^{241}Am(III)$, $^{237}Np(V)$, ^{155}Eu, ^{144}Ce, ^{60}Co, ^{65}Zn, and ^{134}Cs.

Some of the latest experiments included, in addition, ^{95m}Tc, ^{110m}Ag, and ^{54}Mn. The inclusion of ^{95m}Tc may give very interesting results, as ^{99}Tc is now analysed in field samples. Furthermore, two oxidation states of plutonium ($^{238}Pu(IV)$ and $^{239}Pu(VI)$) were included in a single experiment. The work with simultaneous tracing of the two oxidation states is continued.

The reproducibility of results from short-term accumulation experiments with Fucus was judged to be excellent on the basis of the first experimental series from 1981. A series from 1982 also reproduces nicely, but shows significant differences to the 1981 results. Some of the differences may be explained by differences in the algal material used. If this is so it is important not only for the evaluation of laboratory experiments performed at different times, but also for the use of Fucus as monitoring organism.

A series of experiments designed to evaluate a possible seasonal effect on the algal material is being conducted.

The short-term accumulation experiments with Fucus has shown that the initial rate of accumulation is negatively correlated to salinity and positively to temperature for Co, Zn, and Cs. For the transuranics no correlation to temperature and salinity has been found, whereas results for the rare earth elements suggest a salinity effect.

A long-term loss study with Fucus initiated November 1982 partly failed, as the plants died during the spring of 1983. However, during the winter, biological half-lives for Zn and Co were infinitely long, whereas Cs and Eu were lost with an approximately 2-months half-life. The faster loss of Eu compared to Zn and Co might be explained by lack of incorporation in the inner parts of the thallus, whereas Cs as an actively metabolized element is expected to show a fast loss rate.

A long-term loss experiment with Mytilus edulis was started at the Forsmark "Biotest" area in Sweden at the Bothnian Sea. The experiment is still running.

3.2.2. Seawater, sediments, seaplants, and mussels

Through the duration of this project in 1983 we have performed the following sampling expeditions: 1) From April 12 to 15 seaweed was collected along the Irish east coast. 2) From May 25 to June 23 staff members were on board F/S Gauss from the German Hydrographic Institute kindly invited by Dr. H. Kautsky. On this cruise large surface seawater (~ 2 m^3 samples were collected in nearly all parts of the Baltic Sea. The samples are analysed for radiocesium, ^{60}Co, ^{3}H, ^{90}Sr, ^{99}Tc and transuranics. Furthermore, sediment samples and benthos were collected. Along the Swedish and Danish coast we collected at the same time fucoids, which are analysed for γ-emitters and ^{99}Tc.

The purpose of the Baltic sampling has been in general to get an overall picture of the radioactive contamination of the Baltic Sea and in particular to trace the effluent from Sellafield in this region. 3) From June 30 to July 19, Dahlgaard was on board the German ice breaker M/S Polarstern, kindly invited by Prof. E. Augstein, on its cruise from Bremerhafen to Svalbard and North East Greenland. We collected large seawater samples (mostly surface but also some deep samples) up along the Norwegian west coast, between Norway and Svalbard and in the Fram Strait. The samples are analysed for radiocesium, ^{90}Sr, ^{3}H, and transuranics. 4) Finally, Boelskifte was on board the R/V Dana (The Danish Institute for Fisheries and Marine Research, DFH) from Oct. 20 to 27 on a cruise to the southern part of the Baltic Sea, where we collected large seawater samples from surface and bottom for radiocesium determinations.

During 1983 DFH has made four cruises with R/V Dana in the North Sea and the Skagerak and collected 35 surface seawater samples for us. From the Institute for Energy Technology, Kjeller,

Norway we have obtained a seawater sample from Jan Mayen. Finally, the Fishery Investigations of Greenland (GFU) has collected 40 surface seawater samples for us along the Greenland west coast from 63°N to 70°N in July and October.

During the programme in 1983 210 seawater samples have been collected in all.

The analysis of the samples collected in 1982 is finished and the results are reported (see the references). For the sampling of seaweed and mussels along the East Greenland coast and from a comparison with data from samples collected in 1969 we can draw the following conclusion: The concentration ratios

$$\frac{\text{Bq kg}^{-1} \text{ dry weight Fucus}}{\text{Bq l}^{-1} \text{ seawater}}$$

were 185 for ^{137}Cs, $2x10^2$ for ^{90}Sr and $3.8x10^4$ for $^{239,240}Pu$. For Mytilus the ratios were $1.2x10^2$ for ^{137}Cs and $1.6x10^3$ for $^{239,240}Pu$. The ratios for Mytilus were similar to those found at Iceland and the Faroe Islands in 1981. In the case of Fucus the ratio found for Pu in East Greenland was nearly 10 times higher than the mean ratio at Iceland and the Faroe islands. The concentration ratio for ^{137}Cs in Fucus showed no local variation.

The sampling along the coastline of the Northern U.K. in 1982 has shown that the ^{137}Cs as well as the $^{239,240}Pu$ concentrations (C) in seaweed are inversely proportional to the distance (A) (with the current) from Sellafield, i.e. $C=K \cdot A^{-1}$. The $^{241}Am/^{239,240}Pu$ ratios also decrease with the distance suggesting a more rapid removal of Am than of Pu to the sediments. The concentration ratio for Fucus collected in Scotland was 178 for ^{137}Cs, $1x10^4$ for $^{239,240}Pu$ and for ^{241}Am: $0.9x10^4$.

The radionuclides concentration in biota collected close to Sellafield in 1982 are nearly equal to those reported by the M.A.F.F. Lowestoft laboratory in the U.K. for 1981. From the analysis of ^{99}Tc on fucus collected in Scotland, Norway, Sweden, Denmark, Svalbard, Greenland, Iceland and the Faroe Islands it has been shown that ^{99}Tc follows the same pattern as the concentrations of ^{137}Cs in Sellafield effluents collected at these locations. Thus along the Norwegian west coast the ^{99}Tc concentration in seaweed decreases by a factor of two from 59°N to 71°N, just as we have seen for radiocesium in seawater.

The $2m^3$ samples collected in the Danish straits during the Gauss cruise have made a determination of the ^{60}Co content in the Kattegat possible. We found 0.12 Bq m^{-3}. From ^{60}Co measurements in Fucus from the same region we estimate a concentration ratio of 2×10^4. The samples collected during the Polarstern cruise in July 1983 contained ^{134}Cs. The concentration decreased from 0.9 to 0.2 Bq m^{-3} from North Norway to Svalbard.

From Svalbard to 0° longitude at ~ 80°N the concentration decreased to 0.06 and at 10°W, the concentration was <0.007 Bq ^{134}Cs m^{-3}. These observations confirm last year's conclusions, namely that radiocesium from Sellafield has entered the eastern branch of the East Greenland current. From South Norway to Svalbard the radiocesium concentration of the surface seawater decreases by one order of magnitude. We may consider the situation in the North Atlantic as being in equilibrium with regard to Sellafield radiocesium. The discharges of radiocesium (decay corrected to 1983) have been rather constant in the period 1974-1981: 3300 ± 800 TBq ^{137}Cs a^{-1} (± 1 SD, N=8) and 73 ± 13 Tbq ^{134}Cs a^{-1}, and the concentrations in surface seawater have also been nearly constant. This makes it possible to calculate the transfer factors from discharge to the water concentrations at a

given location. When we know the catch of fish, we can then calculate the human intake of radiocesium from Sellafield arising from fish consumption. Such calculations are now possible for the Norwegian and Barents Seas.

3.2.3. Plutonium and americium at Thule, Greenland

We have continued the measurements of Pu and Am in 1-cm layers in the sediment samples collected close to the point of impact in Thule. The studies have shown that our sampling technique does not transfer activity from the upper to the lower layers.

Furthermore, we have seen that even within a very limited area (2 km^2) we can observe large variations in the vertical distribution of the activity, probably due to varying degree of bioturbation. We have also continued our measurements of old samples (from 1968) to determine the ingrowth of ^{241}Am from ^{241}Pu and hence estimate the ^{241}Pu contents.

A new expedition will take place in August 1984.

3.3. Radiation exposure from ingestion of contaminated foodstuffs

As a supplement to earlier assessments of contributions to individual and collective doses from external irradiation and inhalation of radionuclides from routine and accidental releases, the dose contribution from ingestion of contaminated foodstuffs following airborne discharges is estimated by request of the Danish utilities.

Calculations were made to predict the relationship between the rate of discharge of particular nuclides and the radiation exposure of critical groups as well as individuals feeding within an average Danish diet. The critical groups specified are 1) children under one year old because of their comparatively

high milk consumption rates, 2) fishermen who are presumed to consume relatively high amounts of the local catch of fish and shellfish, and 3) vegetarians.

Assuming a discharge of 1 TBq per year of each of the eight most important radionuclides, calculations were made of the individual dose contributions to the different ingredients of the average diet, and to the diet for the three critical groups. The collective committed effective dose equivalent for the total area and for each radionuclide and each ingredient in the average diet was calculated also.

The calculations of the consequences of a 1 TBq discharge will form the basis of later calculations of individual and collective doses from ingestion of contaminated foodstuffs following airborne discharges from routine and accidental releases.

3.4. Activity concentration of radionuclides in coal and combustion products.

As the burning of coal is one source of enhanced radiation exposure to naturally occurring elements, The Danish Environmental Agency wanted measurements of the concentrations of the significant radionuclides in coal of various origins as well as in the combustion products.

On the basis of a previous reading of literature it was decided to measure the concentration of K-40, U-238, Ra-226, Th-232, Po-210, and Pb-210.

As the Danish power plants use a mixture of coal whose origin is difficult to elucidate, gamma measurements were made on samples of the coal mixtures used and the accompanying slag and fly ash from five power plants.

Furthermore, one of the power plants delivered samples of fractionated fly ash. The concentrations of Po-210 and Pb-210 together with gamma activity were measured on all the samples from the power plant in question.

Measurements of gamma activity and concentrations of Pb-210 and Po-210 in samples of coal, slag, fly ash and fractionated fly ash from power plant no.5.

	K-40	U-238	Ra-226	Th-232	Pb-210	Po-210
	Bq/kg dry weight					
Coal	27	57	28	29	9.2 b)	9.2
Slag	159	278	166	156	3.6 b)	3.9
Fly ash	206	286	180	201	117 a)	45
>49 µ	168	230	148	149	39 b)	5.5
35-49 µ	-	-	-	-	-	11
20-35 µ	209	248	187	196	38 b)	85
10-20 µ	176	278	192	198	58 a)	147
3-10 µ	221	434	201	211	190 a)	384
<3 µ	370	649	236	288	497 a)	857

Uncertainties: Measurements of Pb-210: a) 10-30 per cent, b) > 30 per cent.
Measurements of Po-210: < 15 per cent.

The measurements were in accordance with the results found in the literature.

On the basis of the analyses made, the gamma activities from Ra-226 and Th-232 in one year's production of fly ash were estimated. This was compared with the estimated amounts of activity from the same two radionuclides in the phosphate fertilizers which during one year were used in agriculture:

Activity concentration (GBq) of naturally occurring Ra-226 and Th-232 in fly ash and phosphate fertilizers.

	Ra-226	Th-232
Fly ash (100 mill. kg per year)	180	160
NPK (800 mill. kg per year)	180	4.8

A correlation analysis was made to obtain a possible connection in coal between ash production and content of sulfur and between ash production and gamma activity. The coefficients of correlation were 0.08 and 0.73 respectively.

3.5. Membrane lipids in the eel affected by γ-irradiation and other environmental factors

The project aims to study the mechanism of salt transport in marine animals and the way it is changed after high doses of γ-irradiation.

It has recently been shown in our laboratory that the $C_{16:1}$ fatty acid (palmitoleic acid) apparently plays a special role in the mechanism of salt transport by eel gills. This is in accordance with the general concept that the lipid moiety of the cellular membrane has a modifying effect on transport proteins. It seems reasonable to expect changes in membrane function to be accompanied by changes in lipid metabolism within the cell system involved.

The gills are known to be the main site of active salt transport (against concentration gradients) in fish. In the eel, there is further evidence of a hormone-regulated passive salt transport (along concentration gradients) in the esophagus. The fish intestine is regarded as the site of both active and passive salt transport.

Present experiments compare lipid metabolism (in vivo) in the gills, the esophagus, the intestine and the liver of the European eel (Anguilla anguilla). The liver acts as a reference tissue. Eels are kept in fresh as well as in seawater. They are caught either in their normal yellow stage or in their silver stage, which is when they are in a hormonal state ready for spawning migration from brackish water (Roskilde Fjord) to seawater. They are irradiated (10 Gy, total body) in a ^{60}Co-irradiation unit. Lipid metabolism is measured by adding ^{14}C acetate and

^{32}P-phosphate as lipid precursors to the incubation tank. The various lipid classes from each tissue are separated and assayed by thin-layer chromatography. Fatty acids are separated and assayed by paper chromatography, after saponification and acidification.

List of publications

Aarkrog, A. "Risk assessment of long-lived radionuclides in the marine environment". Invited paper to International Symposium on the Behaviour of Long-lived Radionuclides in the Marine Environment, La Specia, 28-30 Sept. 1983.

Aarkrog, A., Bøtter-Jensen, L., Dahlgaard, H., Hansen, H., Lippert, J., and Nielsen, S.P. "Environmental Radioactivity in Denmark in 1982", Risø-R-487, June 1983.

Aarkrog, A., Dahlgaard, H., Hallstadius, L., Hansen, H., Hols, E., and Lippert, J. "Environmental Radioactivity in the Faroes in 1982", Risø-R-488, July 1983.

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Dahlgaard, H. "Transuranics, rare earths and cobalt, zinc and caesium in Fucus vesiculosus (seaweed): Laboratory exercises and field realities". Paper presented at the International Symposium on the Behaviour of Long-lived Radionuclides in the Marine Environment, La Specia, 28-30 Sept. 1983.

Dunic, S., Hallstadius, L., and Holm, E. "A study of the transport of radionuclides in the sea by use of isotope ratios". Paper presented at the International Symposium on the Behaviour of Long-lived Radionuclides in the Marine Environment, La Specia, 28-30 Sept. 1983.

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Holm, E., Persson, B.R.R., Hallstadius, L., Aarkrog, A., and Dahlgaard, H. "Radiocesium and Transuranium Elements in the Greenland and Barents Seas", Oceanol. Acta 6 (1983) 457-462.

Meide, A. "Analyser af radioaktivitetsindholdet i kul, slagge, flyveaske og rengasstøv". (In Danish), 17 pp. 1983.

Nielsen, O.J., "Transfer Coefficients for Sr-90 and Cs-137 in Various Constituents of Human Diet in the Nordic Countries. In Seminar on the Transfer of Radioactive Materials in the Terrestrial Environment Subsequent to an Accidential Release to Atmosphere, Dublin, 11-15 April 1983. Proceedings. Vol. 2. (Commission of the European Communities, Luxembourg, 1983) 455-480.

4. ELEMENTS OF RISK BY NUCLEAR ACTIVITIES

4.1. Gaussian model on atmospheric dispersion

Risø's computer model, PLUCON4, for calculating off-site consequences of releases of fission products to the atmosphere was included in the CSNI sponsored International Comparison Study on Reactor Consequence Modelling. A report on this study was issued in September 1983.

Now Risø participates in the activities of the OECD/CSNI group GRECA (Group of Experts on Consequences of Accidents).

Verification of the dose models included in PLUCON4 has continued. PLUCON4 calculations are being compared with data from atmospheric tracer experiments at the Swedish nuclear power plant Ringhals. A report is due in 1984.

At the request of the Danish utilities, PLUCON4 has been used for calculating annual doses from normal operation of nuclear power plants on three potential Danish reactor sites. The calculations included individual and collective doses from unit releases of a number of important isotopes. Further, an assessment has been made of the consequences of hypothetical accidents at the aforementioned NPP sites.

The concentrations of airborne and deposited radioactive material in the event of a (hypothetical) large accident at a Swedish nuclear power plant were calculated for the Swedish Institute of Radiation Protection.

4.2. Puff-model

A new model PUFFCON, is being developed for calculating the consequences of accidental releases taking into account the variation of the meteorological conditions with time. This model is based on a puff dispersion model. It is a three-dimentional computer model which simulates the release of pollutant puffs and predicts their concentration as they diffuse while being advected downwind by a time-dependent wind.

Calculation of external gamma doses from airborne as well as deposited radioactivity will be included in the model. Thus, the final model will be able to calculate collective doses, of consequences, etc.

Based on the puff model, computer programs have been developed for calculating concentrations of airborne material. Further, a computer programme for graphical presentation of calculation results has also been developed.

Verification of the puff-model using results from experiments performed at Kernforschungszentrum Karlsruhe has started. This is a part of a cooperative programme between Risø and Karlsruhe.

Risø participates in the Nordic SNODAS group (SNODAS stands for "Coordination of Nordic dose calculations and atmospheric dispersion calculations"). It is intended that further development of the puff-model within the Nordic countries should be coordinated by the SNODAS group.

4.3. Behaviour of accidentially released radionuclides in urban areas.

The department has studied contamination from reactor accidents for several years in connection with an assessment of radioactive contamination in Copenhagen following hypothetical core-melt accidents at the Swedish Barsebäck Power Plant.

The information collected during that study is being supplemented by an extensive literature review together with some experimental work with the aim of defining the "state of the art". In the following, a short description is given of the different parts of the work carried out under a subcontract with Association Euratom - C.E.A.

Dry deposition can be estimated by combining the content of cesium-137 in outdoor surface layers with the corresponding time-integrated concentration in the air. For this purpose three samples of outdoor vertical surfaces have been collected under this contract. Further, protected surfaces have been placed on three different buildings with the aim of estimating the dry deposition velocity of particles by later measuring the content of beryllium-7 in them.

In preparing the calculation of shielding factors for representative European buildings, a number of structural parameters have been listed. These include such measures as mass-thickness, building dimensions, window area percentages, and size of the building surroundings. Parameters for both single family and multi-storey buildings in different European countries are being collected by Euratom/CEA. Once this information is gathered, the shielding factors can be calculated.

After measuring the air exchange rate and the time-integrated concentration of beryllium-7 inside and outside three houses, the outdoor/indoor inhalation dose rate for particulate material has been estimated at about 3. This ratio can be increased to about 10 for a room, where a vacuum cleaner is operated, provided that the room is separated from the rest of the house by closed doors.

With a view of measuring the run-off rate from roofs, a set-up has been built carrying different roof materials. The raw construction is finished and will be equipped in the spring.

The removal of radioactivity (rubidium-86) from road surfaces is being studied. The experiments are carried out on four different surfaces: two asphalt areas, one area of old concrete and a section of road made of new concrete. The new road was contaminated in October and the total weathering effect until the end of December was only a few percent. The weathering effects for the three other surfaces were very much the same.

Forced decontamination has been subject to a literature study. This study showed contamination factors varying from 1 to 10 000. The highest factors are obtained where the initial contamination levels are high and the areas small so that decontamination by surface removal is economically acceptable.

4.4. Swedish State Power Board

The Swedish State Power Board, Statens Vattenfallsverk requested a calculation of doses and concentration of activity deposited downwind from a design basis accident at a nuclear power plant. The results were to be compared with the doses and concentrations given in the accident-cataloque "Hand-Emma", applied at the Swedish nuclear power stations. Some minor differences were found to be caused by the use of different dose-conversion factors.

4.5. The Swedish-Danish Barsebäck Committee

The Swedish-Danish Barsebäck Committee suggested in June 1983 that a demographic comparison of the Barsebäck nuclear power plant be made with plants situated near other large cities and national borders.

Sixteen other nuclear power plants: 13 in Western Europe, 2 in USA, and 1 in Canada were chosen for the comparison. Within five discrete distances out to 50 km, the population distributions have been found and compared.

In addition the positions, relative to the power plants, of institutions, administrative centers, communication centers, and other public establishments within the country or in neighbouring countries are mentioned.

Of the sixteen plants investigated, ten are placed closer to neighbouring countries than Barsebäck, all of them have more inhabitants than Barsebäck within a distance of 10 km and six

of them have more innabitants tnan Barsebäck within a distance of 50 km.

Finally, the details of special agreements are given together with negotiations between neighbouring countries or internationally about nuclear power-related matters. These include alarm and emergency procedures and agreements about liability in case of an accident in a neighbouring country.

4.5. Tokamak thermonuclear reactors

Under a contract with the European Fusion Technology Programme a project has been started to estimate the radiological aspects of a Tokamak reactor. The important radiation fields arise from the neutrons and the neutron activation products.

List of publications

Gjørup, H.L., Micheelsen, B., Thykier-Nielsen, S., Consequences of Large Reactor Accidents Calculated on the Basis of Empirical Data. In Nuclear Power Experience. Proceedings, Vienna 13-17 September 1982. Vol. 4. (IAEA, Vienna, 1983) 119-130.

Gjørup, H.L. A review of BEED (Best Estimate from Emperical Data) and CCED (Consequences Calculated on the basis of Emperical Data), Risø. Lecture at RKS-seminar, Stockholm, Sept. 1983.

Gjørup, H.L., Towards Realistic Evaluation of Environmental Consequences of Severe Accidents in LWRs. In Workshop on Pission Product Behaviour during a Hypothetical Severe Accident in LWRs. Rome, 20-21 September 1982. (ENEA, Rome, 1982) 187-197.

Hansen, H.J.M, and Gjørup, H.L., Societal Risk is not just the Sum of Individually Perceived Risks. Comparison of Risks Resulting from Major Human Activities, Avignon, 18-22 October 1982. (Société Francaise de Radioprotection, Fontenay-aux-Roses, 1983) 465-473.

Hedemann Jensen, P. and Heikel Vinther, F., Calculation of Doses from Land Contamination with Long-lived Radionuclides. Comparison of Risks Resulting from Major Human Activities, Avignon 18-22 October 1982, (Société Francaise de Radioprotection, Fontenay-aux-Roses, 1983) 579-585.

Larsen, S.E. and Thykier-Nielsen, S., Description of the Risø Puff Diffusion Model. Risø May 1983.

Lauridsen, B., and Hedemann Jensen P., Shielding Factors for Vehicles to γ-Radiation from Activity Deposited on Structures and Ground Surfaces. Health Phys. 45 (1983) 1039-1045.

Mikkelsen, T. and Thykier-Nielsen, S. "Risø's puff diffusion model for risk and safety assessment", ENEA seminar on "Real-time diffusion models for emergency preparedness", Rome, June 1983.

Mikkelsen, T. and Thykier-Nielsen, S. "Risø's puff diffusion model for risk and safety assessment", Bilateral workshop KfK/Risø on Atmospheric Pollution Research, Karlsruhe, November 1983.

Roed, J. Deposition Velocity of Cesium-137 on Vertical Building Surfaces, Atmospheric Environment 17, 663-664 (1983).

Walmod-Larsen, O. Ongoing research at Risø on dispersion parameters such as deposition parameters, filtering and shielding effects of buildings and vehicles, Risø. Lecture at RKS Seminar, Stockholm, Sept. 1983.

5. NUCLEAR EMERGENCY PREPAREDNESS

5.1. Risø

A revision of the internal emergency plans for radioactivity accidents at Risø National Laboratory was in progress. In 1984 the external plans will be revised.

5.2. Barsebäck power plant

Under the existing co-operation on the Barsebäck Emergency Plan with the Danish Environmental Agency an implementation of computer technique in the emergency communications system is being developed. Two identical computers (HP 9836CU) are installed at the police headquarters in Copenhagen and at the department at Risø. A terminal installed at the civilian defence forces station at Hillerød provides three possible input stations for field measurements. The software necessary for the system is being developed in the department. Other authorities have shown interest in the system.

On the 14th of October Risø participated in the annual Swedish-Danish Barsebäck emergency exercise, as well as in the subsequent evaluation. The technical support center for the Danish organisation which is positioned in the department was manned and took part in the exercise.

5.3 Swedish State Radiation Institute (SSI)

As part of the cooperation with SSI, Walmod participated in December 1983 in the Swedish Forsmark emergency exercise "Övning Valle", as an observer in Stockholm, where the State Power Inspectorate, SKI, and State Radiation Institute acted as advisers to the responsible authority in Uppsala Len and to the Forsmark Nuclear Power Station.

List of publication

Nielsen, F., and Walmod-Larsen, O. KASSANDRA I dose prediction on the basis of meteorological information and dose rate measurement. Statens Strålskyddsinstitut FoV-40/3-83. Marts 83.

Appendix I.

STAFF OF THE DEPARTMENT

Scientific Staff
(number refers to the relevant sections of this report)

Boelskifte Petersen, S (3)
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Christensen, Poul (2)
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Hansen, Heinz (3)
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Lauridsen, Bente (2,4)
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Aarkrog, Asker (3)

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Frost, Ellen Margrethe
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Jensen, Svend Åge Winfeldt
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Pedersen, Anna holm
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Kristensen, Ingrid
Nielsen, Margit
Ullrich, Elisabeth

Appendix 2

Participation in international working groups, etc.

OECD, Nuclear Energy Agency:
Committee on Radiation Protection and Public Health (Gjørup)

CSNI: Principal Working Group IV (Gjørup)

do. Subgroup of Experts on Accident Consequences (Thykier-Nielsen)

CSNI: Working Group on Fuel Cycle Safety (Roed)

Executive Group for Research on Sea Disposal of Radioactive Waste (Aarkrog)

do. Radiological Surveillance Task Group (Dahlgaard)

Commission of the European Communities
Article 31 Committee, Basic Safety Norms (Gjørup)

Article 37 of the Euratom Treaty, Group of Experts (Walmod)

ACPM, Biology and Health Protection (Gjørup)

Study Group on Accident Consequence Assessment (Gjørup)

do. Expert Group C on the Atmospheric Fission Product Dispersion following a Reactor Accident (Thykier-Nielsen)

Group of Technical Experts on Radiation Protection Dosimetry (Christensen and Majborn)

EURADOS, Beta- and Low-Energy Photon Dosimetry (Christensen)

European Atomic Energy Society:
Public Relations Correspondents Group (Walmod)

International Committee for Radionuclear Metrology (Lippert)

Nordic Executive Group for Radioecology (Aarkrog)

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HEALTH PHYSICS DEPARTMENT
Annual Progress Report
1 January - 31 December 1983

Date August 1984

Department or group
Health Physics

Group's own registration number(s)

39 pages + 2 tables + 2 illustrations

Abstract

The report describes the work of the Health Physics Department at Risø during 1983. The activities cover dosimetry, instrumentation, radioecology, risk by nuclear activities and nuclear emergency preparedness. Lists of staff and publications are included.

A great deal of the work in the department is of minor interest to people outside Risø as it represents service functions. Therefore, the main emphasis in the report has been placed on scientific and contractual work.

Copies to

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Telephone: (03) 37 12 12, ext. 2262. Telex: 43116